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STUDIES ON THE SAMPLING METHODOLOGY

OF PEAS FOR YIELD AND QUALITY

by

Pratapsinha Chintamani Pendse

A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Horticulture

Approved:

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Logan, Utah

1959

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INTRODUCTION

Pea[1] growers have much at stake in getting high yields of peas of prime quality. The income accruing from a pea crop grown for processors is determined by the yield as well as quality. Therefore the farmers' efforts are directed toward growing such a crop.

Research workers are interested in knowing the yield of peas with known tenderometer values which will indicate the quality of peas. Present methods of field harvesting are costly and time consuming which tend to limit the number of varieties that can be satisfactorily evaluated for trial.

A comparison of sampling techniques with present harvesting methods would determine whether or not a sampling technique could be used to obtain the yield and quality evaluation without harvesting the entire plot.

Because of errors in vining peas, large plots are required to make evaluation of yields. If a sampling technique would be satisfactory, the field plots could be much reduced in size which would result in a saving in the cost of the trials.

In addition, data were collected on the performance of five commercial varieties of peas in Utah.

Thus the objectives of the investigation were as follows:

1. To determine how good an estimate can be obtained by taking a sample of the crop in comparison with the complete harvest.

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[1]Pisum sativum, L.

2. To indicate what size of sample is practical and economically plausible.

3. To test the performance of five commercial pea varieties.

REVIEW OF LITERATURE

Field Plot Technique in Vegetable Crops

Plot technique studies with vegetable crops are not numerous. Lana, Homeyer, and Haber (9) reviewed the status of field plot techniques with vegetable crops in 1953. They reported that the heterogenous nature of the various types of vegetable crops makes it virtually impossible to transfer results of plot studies from one crop to another, and that the diversity of vegetable crops with reference to number of harvests presents the greatest problem.

In order to determine the optimum size and shape of plot most of the workers have utilized the coefficient of variability as a device. Lana et. al. (9) pointed out that the coefficient of variability decreased as plot size increased. However, land use economy decreased as plot size increased. The same workers (9) stated that the coefficient of variability is unusually large for vegetable crops; the desired coefficient of variability for vegetable crops being around ten per cent. In their work on beans, carrots, sweet corn and cauliflower, Moore and Darroch (10) found that plot precision, as measured by coefficient of variability, appears to be high for vegetable crops studied, and varies for different crops. A number of factors were found to reduce plot precision. When treatment number was higher than six, coefficient of variability increases from 0.4 to 2.9 were obtained, with sweet corn and spring cauliflower showing the greatest increases. Block and plot shape also had an important effect on efficiency. With sweet corn and fall cauliflower, coefficients of variability were 4.7 and 3.3 higher, respectively, resulting from use of other than optimum plot shape. Block shape was most important with pole beans, where the coefficient of variability was 2.9 higher when shape was somewhat less than ideal.

Field plot technique data on potatoes, which are the most voluminous studies among vegetable crops, show that a long narrow plot is most desirable. Krantz (8) and Currence and Krantz (2) suggest a plot one row by two rods. Justeson (6) and Kalamkar (7) obtained results similar to those of the above workers. In a uniformity trial study on tomatoes, Currence (3) using eight hundred and sixty four plants harvested singly and assuming six treatments found that the coefficient of variability for date of ripening, early yield and total yield decreased as plot size increased. Strickland (19) in his uniformity studies with tomatoes pointed out the optimum plot size to be thirty six plants distributed as two rows of eighteen plants each. For either four or sixteen different treatments Hartman (5) found that single row plots ninety six feet long seem preferable to four row plots twenty four feet long when rows are spread six feet apart.

In their plot technique studies with navy beans, Down and Thayer (4) concluded that the three row plot thirty feet long with rows twenty eight inches apart, discarding the border rows, was the maximum width needed to give accurate comparison. Moore's (11) data on sprouting broccoli utilizing ten plant units showed that plot shape had no consistent effect on standard error. The large experimental errors were attributed to the heterozygous nature of the commercial strain, the variability of the alluvial soil upon which the study was made and the effect of multiple harvests.

In a recent study on sweet corn and peas, Nonnecke (12) reported that the coefficients of variability for sweet corn increased with plot size. For canning peas the coefficient of variation for both vines and shelled peas showed an overall reduction as plot length increased. Optimum plot size for sweet corn was found to be one or two basic units (ten feet by six feet or twenty feet by three feet) depending upon cost assumed and the value of the regression coefficient. For canning peas the optimum plot size was found to be one basic unit (five feet by ten feet). The optimum size of plot for yield of sweet corn provided sufficient kernels for quality studies. However, for canning peas considerably more shelled peas were required for processing than can be obtained from the optimum size of plot for yield.

Quality Studies

Size Distribution

In their maturity studies with canning peas Pollard, Wilcox and Peterson (13) found that with the change in maturity the percentage of sieve grades varied. Salunkhe, Pollard, and Taylor (14) screened peas into four sizes as follows:

Sieve Size	Description
1-3	Peas passed through a 5/16 inch screen.
4	Peas held on a 5/16 inch screen, but passed through a 6/16 inch screen.
5	Peas held on a 6/16 inch screen, but passed through a 7/16 inch screen.
6	Peas held on a 7/16 inch screen.

Wattana (21) separated peas in different size groups in a manner similar to that described by Salunkhe, Pollard, and Taylor (14).

Tenderometer Values

Sayre (17) reported that the tenderometer and maturometer satisfactorily measured the quality of raw peas within the limits of accuracy of field sampling. There was an extraordinary variation in maturity of field grown peas and a number of samples had to be taken from a field to judge its maturity accurately. Vittum and Hamson (20) noted that pea growers received highest prices for peas of relatively low tenderometer value (88 to 98 for freezer varieties, and 95 to 105 for canning varieties).

Microscopic Examination of Starch Grains

Barnham, Wagoner, Williams, and Reed (1) stated that the structure of starch grains was influenced by varietal and environmental factors. Salunkhe and Pollard (15) stated that potato tubers having high specific gravity had more distinct lamellae and hyla development in their starch grains than in those of potatoes with low specific gravity. Sharma (18) found that the higher the specific gravity of the potato tubers, the higher was the percentage of large starch grains. Salunkhe and Pollard (16) concluded that, as the maturity of lima beans advanced the starch grain size became larger and the lamellae and hyla became more prominent. Wattana (21) found that the starch grain size increased as the size of peas increased. He noticed in peas there were many different shapes of starch grains and that as the size of peas increased the structural development of the hylum also increased.

MATERIALS AND METHODS

Five varieties of peas, Early Perfection, Dark Seeded Perfection, Perfection Freezer, New Line Perfection and W. R. Perfection were planted at the Farmington Research Station, Farmington, Utah, on April 19, 1958. Of these five varieties, Early Perfection, New Line Perfection, and W. R. Perfection were dark seeded types. The other two varieties were the regular perfection type. A randomized block design with six replications was used. Each plot was 16 feet wide and consisted of 32 rows, each row being 30 feet in length. The weeding and irrigation were done as often as needed. The crop showed a full and vigorous growth one month after seeding. All seven varieties were free of diseases and insects during the growing season.

Peas were harvested once. The harvest date began July 1, 1958 and ended July 5, 1958. The harvesting was done usually in the early morning hours.

Method of Sampling

Eight, one foot long wooden rods were thrown at random in each plot from which the samples were collected. Early Perfection, Dark Seeded Perfection and Perfection Freezer were the varieties used for the sampling study. The plot was divided in two halves longitudinally and four one foot long rods were thrown at random in each of the two halves. All plants in the nearest drill row included in the foot-length of the rod were pulled and counted to get plant density. After this, a few more plants to make a total of 30, were pulled from the vicinity of the sample. This number was arrived at when it was found that 30 plants yielded enough peas to make alcohol slurries, take tenderometer readings, and to conduct size distribution studies.

Each complete sample thus consisted of eight grab samples, and four such samples were collected from a plot. The grab samples were then mixed together, bagged and transported to the processing shed. The pods from samples were picked by hand and shelled by a vining machine. The remaining plot was harvested and shelled by the viner.

The two varieties, New Line Perfection and W. R. Perfection, that were not used for sampling studies, were pulled, harvesting the plot in longitudinal halves separately, and shelled in the viner. After vining the shelled peas were weighed to determine the total yield.

Computation of Yield Per Acre from Samples

The plant density count was used to find the number of plants per foot. From the total number of plants harvested in a complete sample consisting of eight random grab samples, the number of feet harvested was found by using the figure on plants per foot length. Once the length of row harvested was thus obtained, the yield per acre was calculated from the square feet area covered by the sample and yield of shelled peas in the sample.

Qualitative Studies

Subsequent to harvesting, the shelled peas were utilized for the following studies:

Size Distribution

The shelled peas were classified into six different size groups, as given below. Peas of size 2 were designated as the ones which were screened through sieve 18. Peas of size 3 were designated as the peas which screened through sieve 20 but were held on a 18 size sieve. Peas of size group 4 were designated as the peas which screened through 22 sieve but were held on 20 size sieve. Peas of size group 5 were designated as the peas which were screened through number 24 sieve but were held on number 22 sieve. Peas of size 6 were designated as the peas which were screened through number 26 sieve but were held on number 24 sieve. Peas of size 7 were designated as the peas which were held on a number 26 sieve.

Tenderometer Values

The tenderometer was filled with peas, the lever was let off, and the value on the scale was read and recorded. A duplicate reading was taken in each case and the average of the two was used as final value. The box was washed carefully every time after use. (Fig. 1)

Microscopic Examination of Starch Grains

From each size group random samples were obtained after removing shrivelled peas. The samples were washed with water. Composite samples were also collected from each variety. Samples of different varieties and peas of each size group were preserved by making slurries in 95 percent ethyl alcohol with the aid of a Waring blendor.

Just before the samples were studied under the microscope, the slurry was shaken vigorously for uniform dispersion. A drop of this stirred slurry was deposited on a slide and to it was added a drop of distilled water, and the coverslip was put on. The size, shape and hylum of starch grains were viewed under the 43 X objective lens and a 10 X ocular. Ten starch grains were chosen at random on each slide for observation and 10 slides were studied for each sample. The starch grain size in microns was found with an eyepiece and stage micrometer. The shape of the starch grain was classified as circular or irregular. The following subjective classification was used for the Hyla, Wattana (21)

Class of Hylum	Description
1	No hylum development (Fig. 3)
2	Slight hylum development
3	Moderate hylum development and small ramifications
4	Abundant hylum development and large ramifications (Fig. 4)

By the aid of a camera lucida the structure of starch grains was sketched. (Fig. 2) Data obtained in these investigations were analysed for statistical significance.

Fig. 1 Tenderometer

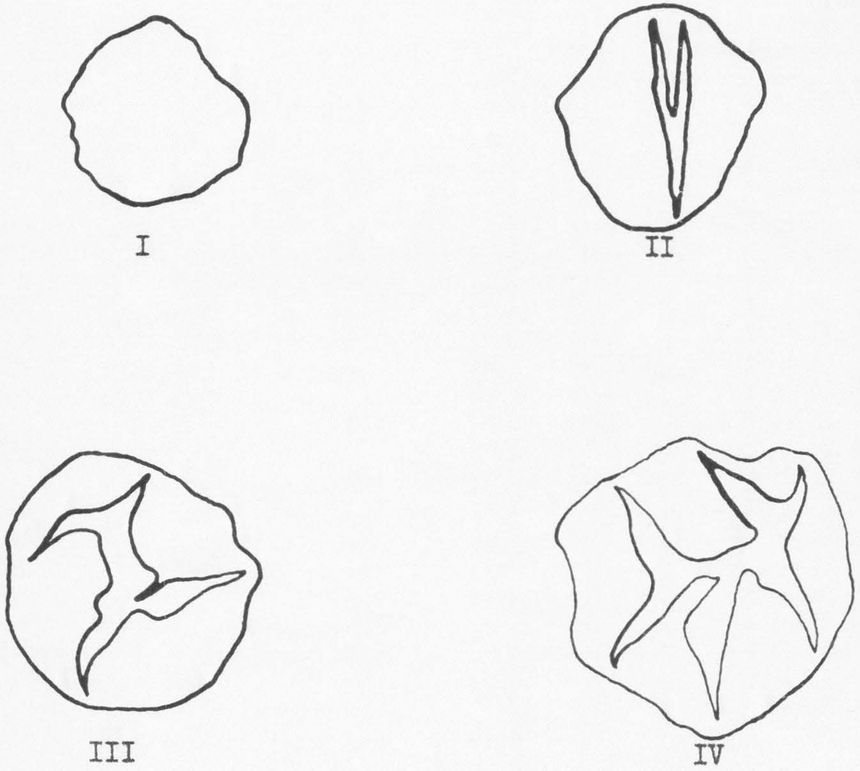

Fig. 2 Classification of hyla of starch grains of peas.

1. No hylum development
II. Slight hylum development
III. Moderate hylum development
IV. Abundant hylum development

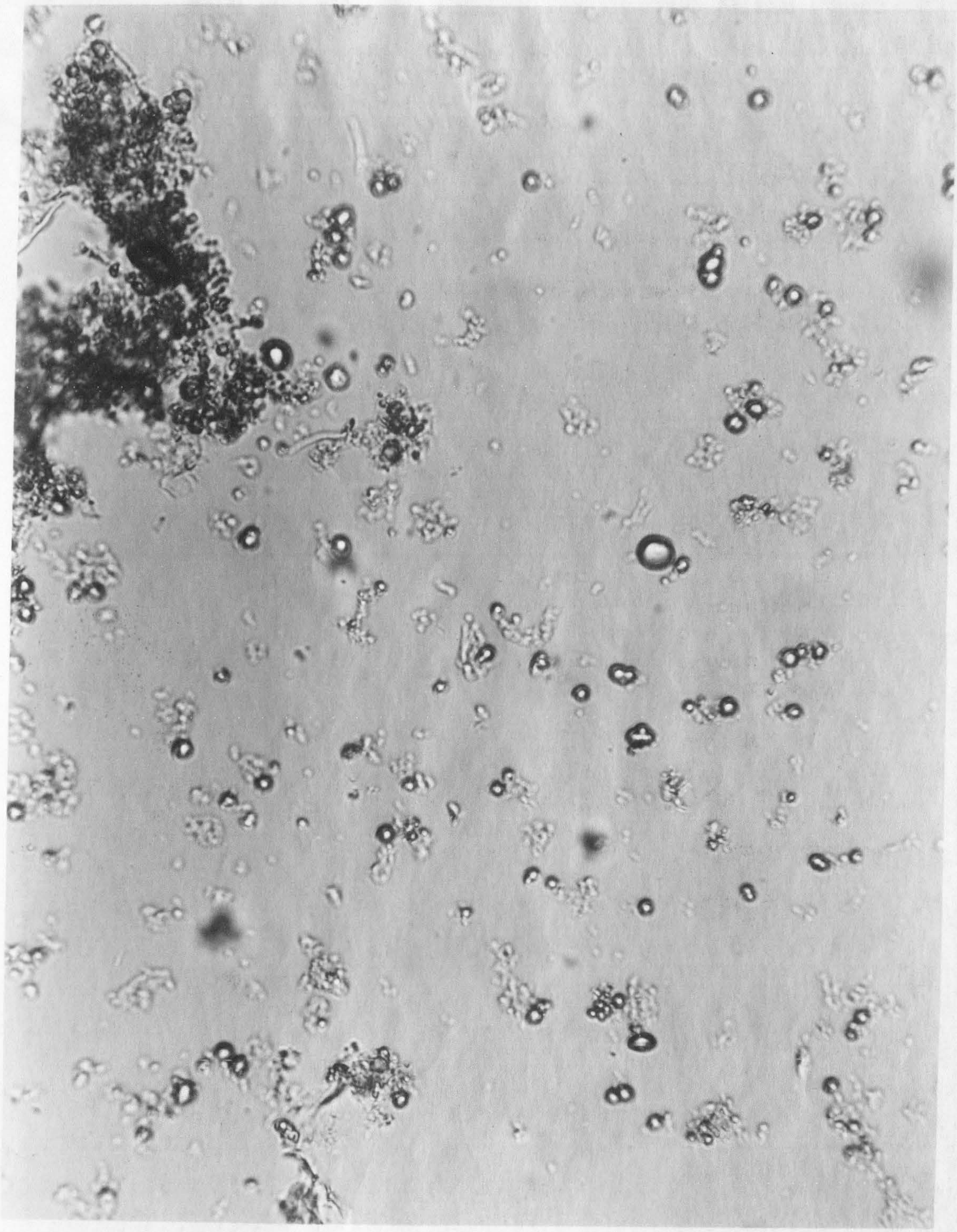

Figure 3. Starch grains of peas of size group 2-3. Compare with figure 4, noting size and shape of starch grains and hylum development.

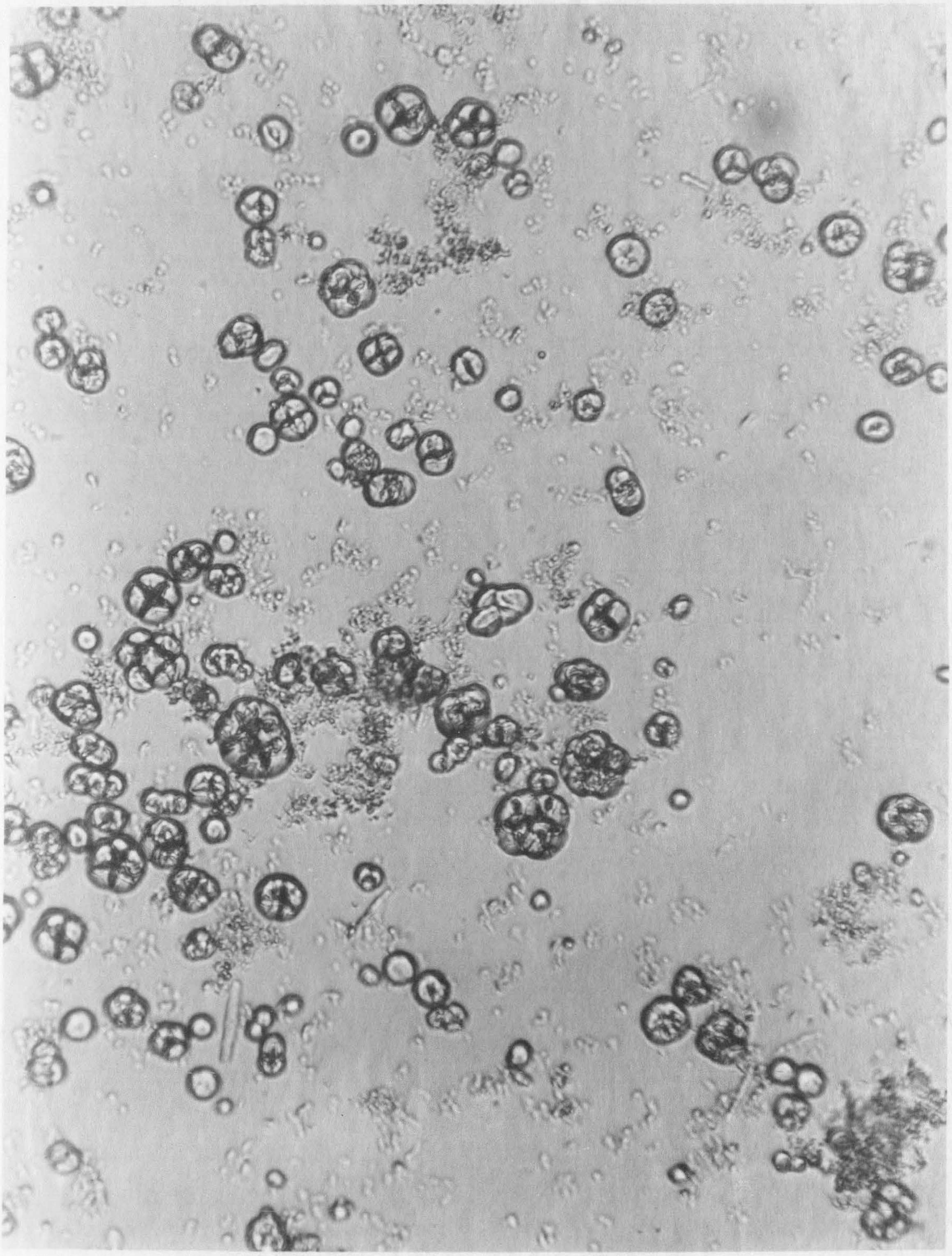

Figure 4. Starch grains of peas of size group 6-7. Compare with figure 3, noting size and shape of starch grains and hylum development.

RESULTS AND DISCUSSION

In order to find out the proper size of sample and the number of replications required to give a set precision, the following data was statistically processed.

1) Yield of peas in lbs. per acre from a complete harvest and from samples.

2) Tenderometer readings of an overall sample from the whole plot and those of the sample harvests.

The data from the harvest of half the plots was used to find the optimum size of the plot and the number of replications required.

The precision of the experiment was set to define the true treatment difference by means of the observed experimental difference ±5, 10, 20 percent of the overall mean, with 95 percent confidence. Appendix tables 26, 27, 28, 29 show the yields and, Analysis of Variance of the half plot harvests, whole plot harvests and sample harvests.

Appendix table 23 shows the variance of mean of samples for different sample sizes and different number of replications. Fig. 5 is plotted from the data in appendix table 23. The results in terms of sample size necessary for stated precision (5, 10, 20 percent of the general mean with 95 percent confidence) are shown in Fig. 5 where curves connect points of equal precision over the range of 4-32 replications on the horizontal axis. Each curve in Fig. 5 is for a particular level of precision.

An experimenter planning an experiment in which he intends to study the yield characteristics (and also for another characteristic presented in Fig. 6) can determine from the graph the number of

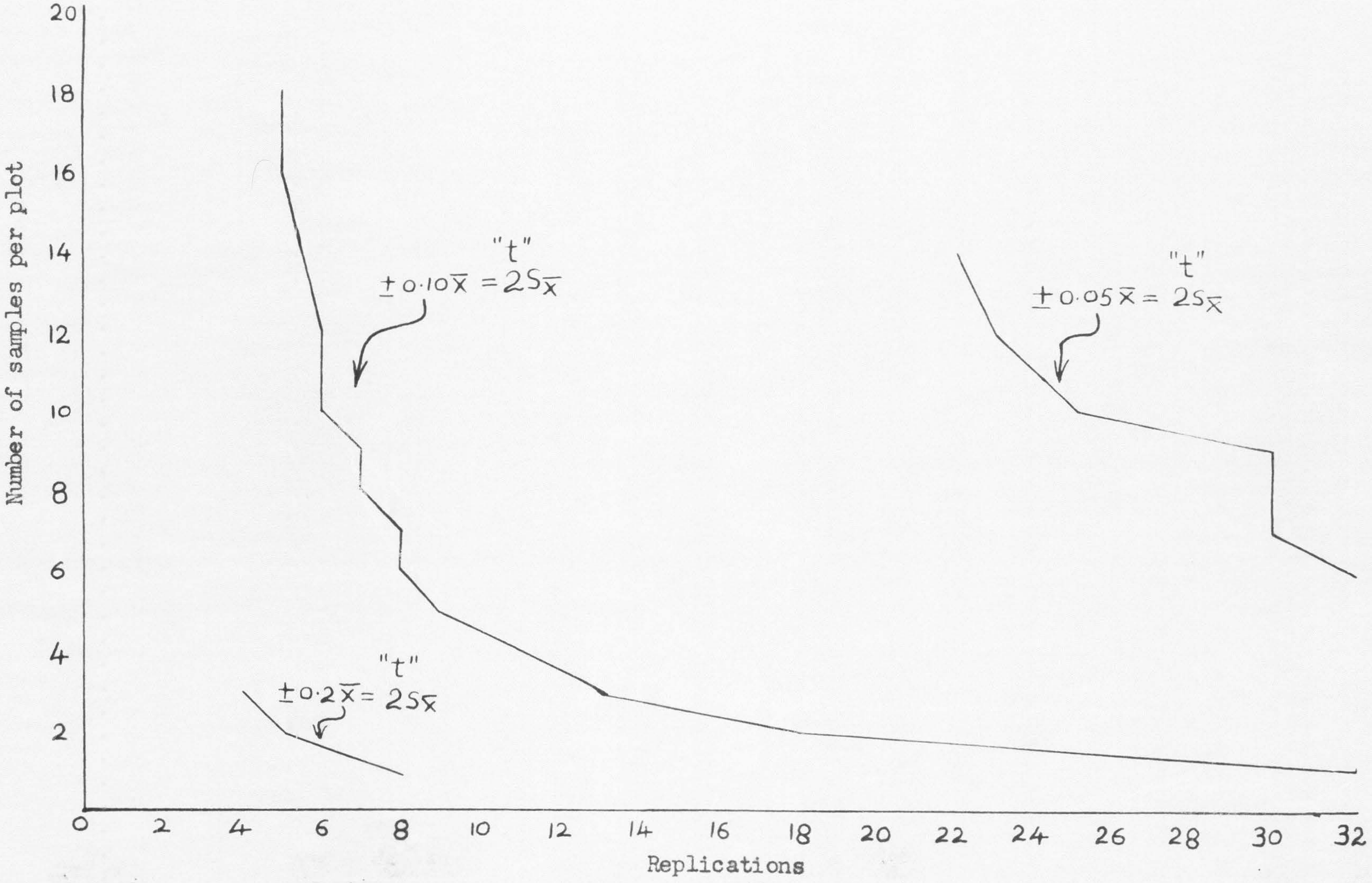

Fig. 5 Number of samples per plot necessary to define with 95 percent confidence a treatment mean difference = the stated percentage of the general mean for varying number of replications, on yield of shelled peas in lbs/acre.

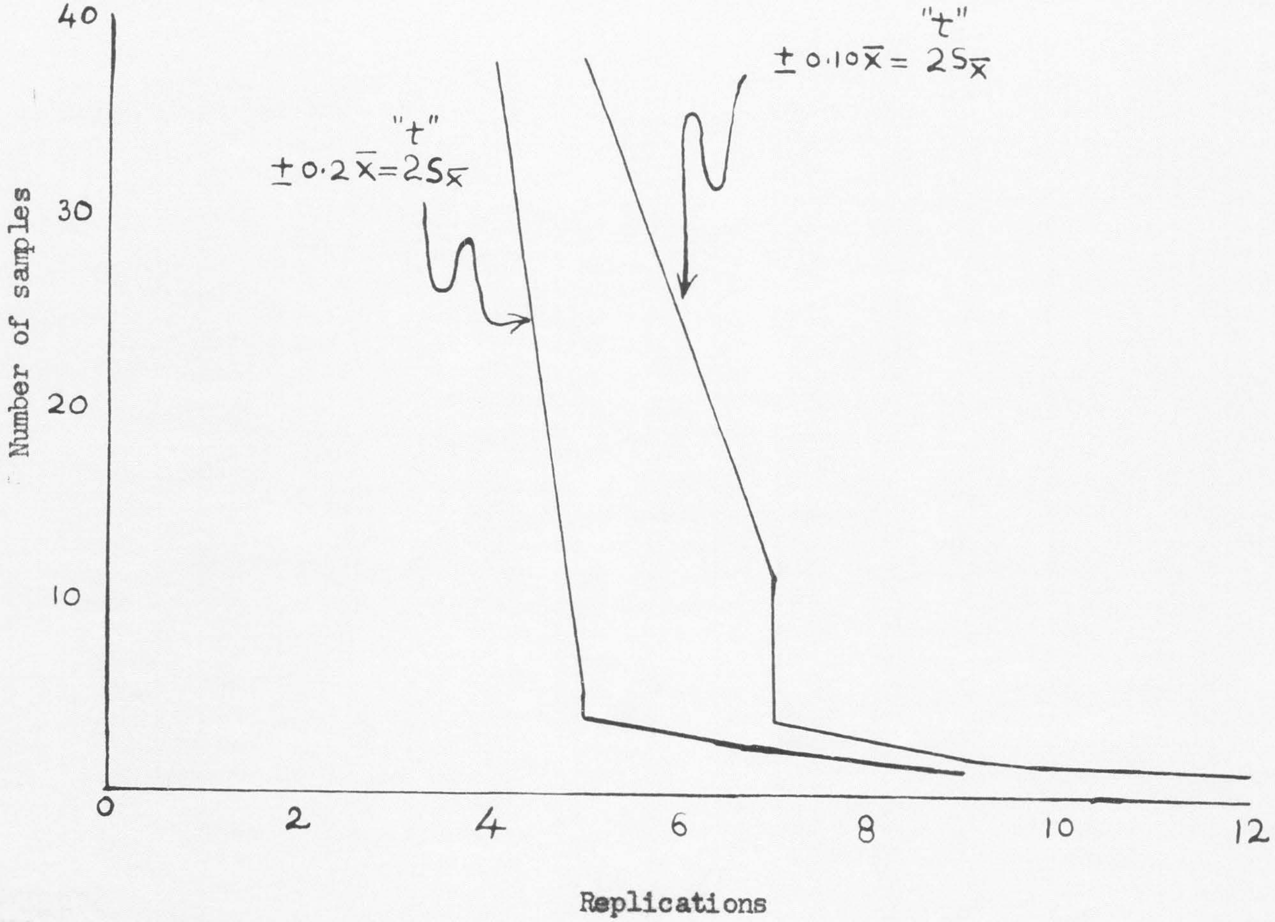

Fig. 6 Number of samples necessary to define with 95 percent confidence a treatment mean difference = the stated percentage of general mean for varying number of replications, on tenderometer reading of peas.

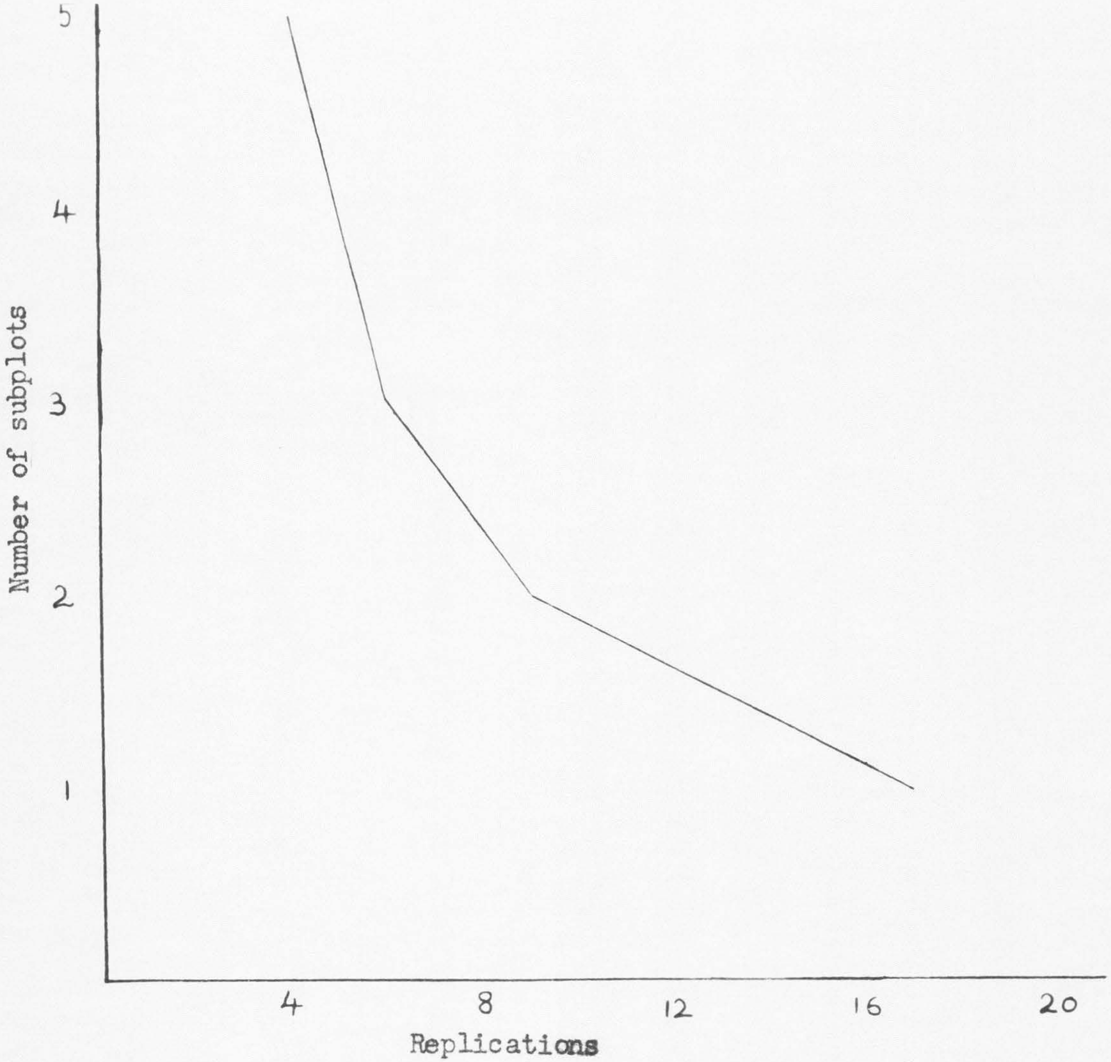

Fig. 7 Number of subplots necessary to define with 95 percent confidence a treatment mean difference = 10 percent of the general mean for varying number of replications, on yield of shelled peas in lbs/acre.

replications and the size of sample that will be needed from each plot to attain the precision shown on the graph.

From Fig. 6 it can be seen that six samples per plot are necessary to define with 95 per cent confidence a treatment mean difference = ten percent of the general mean with eight replications. When the precision is at twenty percent then 3 samples per plot are necessary with four replications. As the precision gets sharper, i.e. at five percent precision 14 samples per plot are necessary with 22 replications.

Fig. 7 shows the number of subplots with different number of replications, that are required to define with 95 percent confidence a treatment mean difference = ten percent of the general mean for varying number of replications. From this figure the optimum size of the plot can be found for this study. If the size of the plot is to be reduced to half of what has been used 17 replications will be necessary but the number of replications goes down to four if two and a half times the present size is used. For one and a half times the present size of the plot, six replications will be required.

In comparing the precision obtained from sampling in comparison with complete harvest, it is seen that nine replications with complete harvest are equivalent to ten and a half replications with sampling. The interchangeability of size of samples and replications to achieve a given degree of precision with sampling procedure can be found. For a varietal test on peas or a similar experiment one could go down to a single row and adjust them according to a population count. Thereafter he has just to take the adequate number of samples which can be found from the graphs in this study and from the samples get a precise estimate of the yield of the variety concerned. Sampling is more efficient and economic, because, in the amount of time required to harvest and thresh the whole plot, several samples can be processed. Besides, threshing a sample would not involve elaborate machinery. Thus, from the economic point of view sampling is more feasible than a complete harvest. Regardless of how many samples you take, more than five replications are necessary to reach desired precision of 10 percent. (Fig. 5)

In both the sampling trial and half plot harvest the effect of replications is the same. Effect of increasing the number of samples is not very prominent.

If only one sample is taken more than 32 replications are required. With four samples about 11 replications are required. The general equation is

$$S_{\bar{x}}^2 = \frac{\sigma_s^2 + K\sigma_p^2}{rK}$$

Appendix table 24 shows the variance of mean of samples for different sample sizes and different number of replications on tenderometer reading of peas. These data are represented in Fig. 6 with plotted points which stand for the appropriate number of samples required with a particular number of replications for obtaining 10 percent and 20 percent precision within the general mean. With 10 percent precision, 4 samples with five replications give as good an estimate as would be obtained by taking the tenderometer reading after the whole harvesting is done. This information will be very useful to canners, who can take the adequate number of grab samples for obtaining an exact estimate of the tenderometer reading of the whole crop. Once a limit of four samples is reached, no further efficiency is achieved by increasing their number, because such an increase does not give the advantage of a corresponding decrease in the number of replications.

Biases in the experiment

The main **bias that was run** into, eas in getting the yield data from the sample harvests. The yields are high by samples in comparison with the complete harvest. Although the plant population in the linear sample length was adjusted by the help of density counts, it could not eradicate the error element which entered in picking out the linear sample. As the one foot rod was thrown in the plot at random, the plant that fell closest to it inside the footlength was grabbed first. Often times the rod might have fallen away from the plants which really represented the true population density. The randomness of the samples could have taken care of this error, yet the large bias that entered the experiment was in calculating the yield per acre from the sample harvests. Due to the failure of the drill to sow seeds right from the beginning of the plot to the end, some unseeded area was left. Where as the complete harvest accounted for the yield of peas as they stood in the plot, the yield procured from the sample harvest represented the yield as would have been available had the rows of peas been entire all over the plot, in the entire experiment.

Also a bias exists in measurement of yield based on shelled peas obtained from the viner as compared to samples shelled by hand. A certain percentage of peas is lost in the viner whereas the recovery from hand shelling would be nearly 100%.

This bias can be nullified by assuring an optimum population by careful drilling or by adjusting for the actual length of the row, even in complete harvest, by removing a foot width of peas from both ends first.

The mean squares of the whole plot harvest and sample harvests in lbs. per acre Analysis of Variance are estimates of the following quantities:

Whole Plot Harvest

Source	Mean Square an estimate of
Rep.	$\sigma^2 + \frac{3}{5}\sum_{i=1}^{6} \beta_i^2$
Var.	$\sigma^2 + \frac{6}{2}\sum_{j=1}^{2} r_j^2$
Error	σ^2

Samples

Source	Mean Square an estimate of
Rep.	$\sigma_\eta^2 + 4\sigma^2 + \frac{12}{5}\sum_{i=1}^{6} \beta_i^2$
Var.	$\sigma_\eta^2 + 4\sigma^2 + \frac{24}{2}\sum_{j=1}^{3} r_j^2$
Error	$\sigma_\eta^2 + 4\sigma^2$
Sampling	σ_η^2

This assumes that we have six replications, three varieties and four samples.

Relative Costs:

The economics of sampling in comparison with that of whole plot harvests is an important consideration in deciding the practical application of the former. To get the same precision there are points of interchangeability between samples and a complete harvest. In estimating the yield of shelled peas with 95 percent confidence and a precision of the experiment to define the true treatment difference by means of the observed experimental difference $\pm$ 10 percent of the overall mean, four samples with two replications are equivalent to whole plot harvest

Table 1

Variance of Mean of Whole Plot and Four Samples for Different Number of Replications From Data on Yield of Shelled Peas.

Variance of Mean / Replications	Whole Plots	Four Samples
1	317,718.5000	370,145.5000
2	158,859.2500	185,072.7500
3	105,906.1666	123,381.8333
4	79,429.6250	92,536.3750
5	63,543.7000	74,029.1000

This table is represented in Figure 8.

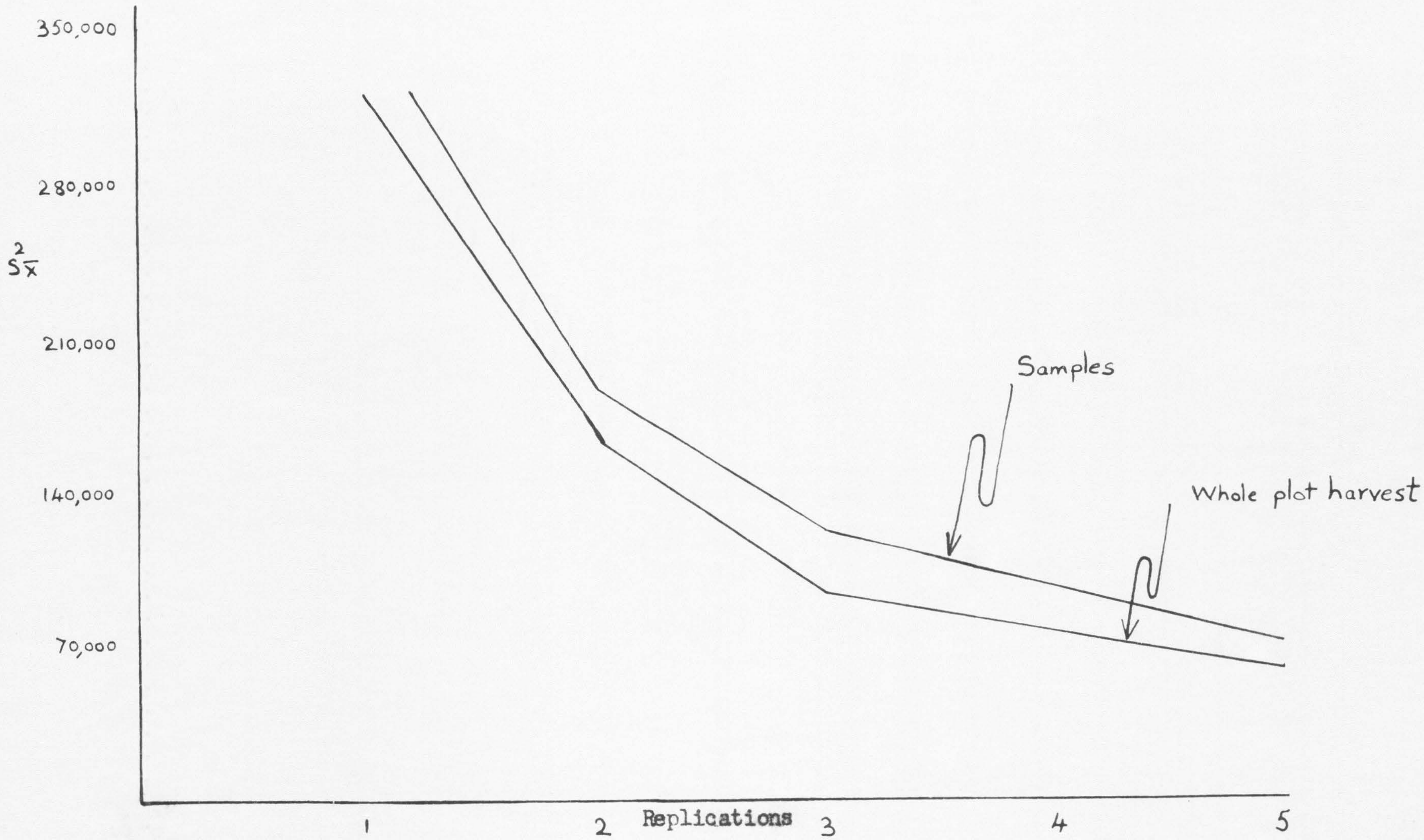

Fig. 8 Variance of mean of whole plots and four samples for different number of replications, on yield of shelled peas in lbs/acre.

with the same number of replications (Table 1). The time required for the former is $\frac{1}{2}$ man hour as against the $1\frac{1}{2}$ man hours needed for the complete harvest of two replications. Sampling is evidently economic for the desired precision.

Varietal Trial of Peas

Yield of Shelled Peas

Tables 2 and 3 show the yield in lbs/acre based on total harvest of five varieties of peas under study and the Analysis of Variance of the same. In varietal trials the yield is the primary consideration, because the economic success of the crop is decided mainly by this criterian. The Analysis of Variance of the data shows that the experiment is not significant. That is, there was no difference in yield of the five varieties of peas.

Tenderometer Values

The tenderometer values obtained on shelled peas of five varieties and their Analysis of Variance are presented in tables 4 and 5 respectively. The results are significant at 5 percent level. The varieties, Perfection Freezer, W. R. Perfection, and New Line Perfection are not statistically different from each other.

The five varieties can be arranged in a descending order as follows:

Name of Variety	Av. Tenderometer Value
Perfection Freezer	101.16
W. R. Perfection	104.53
New Line Perfection	111.50
Early Perfection	114.00
Dark Seeded Perfection	118.49
S.E.	3.84

Table 2

Yield of Shelled Peas in Lbs/Acre

Replication / Variety	I	II	III	IV	V	VI	
Early Perfection	5120	5868	4517	5689	4467	5159	5136.66
Dark Seeded Perfection	4669	5590	5891	5956	5721	6168	5665.83
Perfection Freezer	3940	6815	5233	5400	5251	5274	5318.83
New Line Perfection	5216	4898	5352	3220	5307	5352	4890.83
W. R. Perfection	4319	5443	4626	4331	5443	4853	4835.60

Table 3

Analysis of Variance of Yield of Shelled Peas in Lbs/Acre

Due to	D.F.	Variance	Cal.F.	Table F. 5%	Table F. 1%
Total	29	509,477.0758			
Rep.	5	679,272.0800			
Var.	4	688,070.6250	N.S. 1.5953	2.87	4.43
Error	20	431,309.6150			

Table 4

Tenderometer Values of Peas

Replication / Variety	I	II	III	IV	V	VI	Mean
Early Perfection	118	129	98	126	107	106	114.00
Dark Seeded Perfection	143	122	111	111	105	119	118.49
Perfection Freezer	113	110	94	95	92	103	101.16
New Line Perfection	127	104	124	91	105	118	111.50
W. R. Perfection	118	104	96	98	108	102	104.53

S.E. = 3.84

Table 5

Analysis of Variance of Tenderometer Values of Peas

Due to	D.F.	Variance	Cal.F.	Table F. 5%	Table F. 1%
Total	29	156.30			
Rep.	5	313.34			
Var.	4	300.875	3.395*	2.87	4.43
Error	20	88.625			

The varieties W. R. Perfection, New Line Perfection, and Early Perfection are linked. Similarly the varieties New Line Perfection, Early Perfection, and Dark Seeded Perfection are linked. Perfection Freezer has significantly lower tenderometer value than Early Perfection and Dark Seeded Perfection. W. R. Perfection is significantly superior to Dark Seeded Perfection.

Starch Grain Characters

Size of Starch Grains

Tables 6 and 7 show the starch grain size in microns of the five pea varieties studied, and their Analysis of Variance respectively. There is no significant difference in the size of starch grains of the five varieties. Wattana (21) had arrived at similar conclusions while studying the starch grains of four other varieties of peas.

The regression of starch grain size on pea size shows that (fig. 9 and table 8) there is a highly significant and definite, positive correlation. With an increase in the size of peas there is an increase in size of the starch grains.

Shape of Starch Grains

Tables 9 and 10 indicate that there was no difference in the five varieties as to the distribution of circular or irregular starch grains. The circular shape of the starch grains was common, being possessed by more than 90 percent of the starch grains in all varieties. Wattana (21) had made a similar observation.

Hylum Development

A comparison among the five varieties from the hylum development

Table 6

Starch Grain Size in Microns of Peas

Replication / Variety	I	II	III	IV	V	VI	Mean
Early Perfection	16.905	14.560	10.535	16.765	15.050	15.085	14.816
Dark Seeded Perfection	15.750	12.670	15.540	14.735	12.180	14.070	14.157
Perfection Freezer	14.000	13.370	11.305	12.670	15.260	14.2452	13.475
New Line Perfection	14.910	15.750	14.385	11.200	11.865	14.000	13.685
W. R. Perfection	11.970	12.180	11.340	11.690	12.320	12.180	11.946

Table 7

Analysis of Variance of Starch Grain Size of Peas

Due to	D.F.	Variance	Cal.F.	Table F. 5%	Table F. 1%
Total	29	3.131			
Rep.	5	2.399			
Var.	4	6.819	N.S. 2.646	2.87	4.43
Error	20	2.577			

Table 8

Analysis of Variance of Regression of Starch Grain Size on Pea Size

Due to	D.F.	S.S.	Variance	Cal.F.	Table F. 5%	Table F. 1%	r^2
Total	5	66.336					
Regression	1	62.591	62.591	** 66.87	7.71	21.20	.94
Error	4	3.745	0.936				

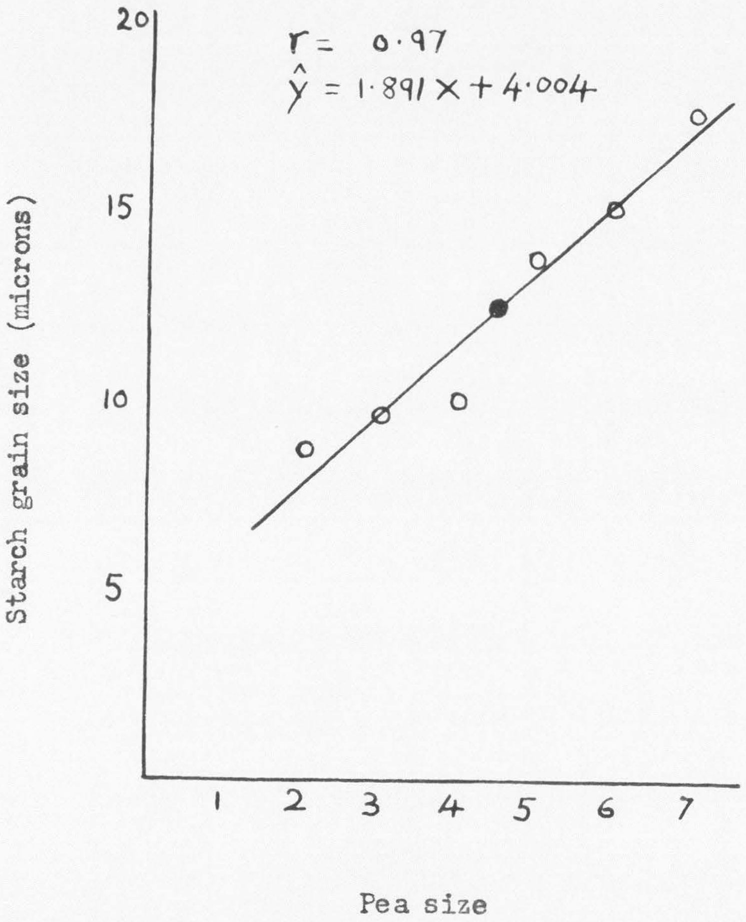

Fig. 9 Regression of starch grain size on pea size

Table 9

Shape of Starch Grains Expressed as Percentage of Round or Irregular

Variety	Replication	I	II	III	IV	V	VI	Mean
Early Perfection	Circular	95	97	95	97	98	76	93.00
	Irregular	5	3	5	3	2	24	7.00
Dark Seeded Perfection	Circular	98	90	95	99	95	93	95.00
	Irregular	2	10	5	1	5	7	5.00
Perfection Freezer	Circular	93	98	99	97	86	99	95.33
	Irregular	7	2	1	3	14	1	4.66
New Line Perfection	Circular	86	95	97	94	96	100	94.66
	Irregular	14	5	3	6	4	-	5.33
W. R. Perfection	Circular	92	96	88	92	84	92	90.66
	Irregular	8	4	12	8	16	8	9.33

Table 10

Analysis of Variance of Shape of Starch Grains

Due to	D.F.	Variance	Cal.F.	Table F. 5%	Table F. 1%
Total	29	28.40			
Rep.	5	15.17			
Var.	4	22.46	N.S. 0.68	2.87	4.43
Error	20	32.90			

point of view shows that, in considering, the first hylum class, there was no difference in varieties Early Perfection, Dark Seeded Perfection, Perfection Freezer, and New Line Perfection (Table 11, 12). Variety W. R. Perfection showed the maximum number of starch grains with hyla of first class and in that respect it was significantly different from the other four varieties. As the maturity of the crop advances the structural development and ramifications of hylum increase. W. R. Perfection thus seems to be a late variety because it has the highest percentage of starch grains with little or no hylum development.

A study of the number of starch grains with hyla of fourth class also indicated that variety W. R. Perfection was a late variety and it had a significantly less number of starch grains having class 4 hyla than all the other varieties with the exception of Perfection Freezer (Tables 13, 14). Here again the presence of the smallest number of starch grains with the most developed hyla was indicative of that variety being a late variety. In the respect of hyla of fourth class, for the varieties Early Perfection, Dark Seeded Perfection, Perfection Freezer and New Line Perfection, the numerical values of such starch grains were not significantly different from one another.

When the number of starch grains with hylum development of the 2nd and 3rd class were considered (Tables 15, 16, 17, 18) statistical significance was not noticeable. These two stages of hylum development seemed to be transitional and they did not differentiate any one variety from the others on that account.

The Influence of Pea Size on Hylum Development

It is evident from tables 19, 20 and figures 10, and 11, that there is a significant, positive correlation between the pea size and the

Table 11

Number of Starch Grains with Class 1 Hylum

Replication / Variety	I	II	III	IV	V	VI	Mean
Early Perfection	21	41	80	18	38	41	39.8
Dark Seeded Perfection	21	49	16	22	62	30	33.3
Perfection Freezer	40	38	59	45	29	28	39.8
New Line Perfection	26	21	40	76	59	39	43.5
W. R. Perfection	72	53	72	72	64	66	66.5

S.E. = 7.1

Table 12

Analysis of Variance of Starch Grains With
Class 1 Hylum

Due to	D.F.	Variance	F. Value Cal.	F. Value Table 5%	F. Value Table 1%
Total	29	382.937			
Rep.	5	221.120			
Var.	4	979.800	3.22*	2.87	4.43
Error	20	304.020			

Table 13

Number of Starch Grains With Class 4 Hylum

Replication / Variety	I	II	III	IV	V	VI	Mean
Early Perfection	46	29	5	53	32	19	30.6
Dark Seeded Perfection	47	21	31	32	13	33	29.5
Perfection Freezer	29	30	13	10	23	22	21.1
New Line Perfection	25	35	26	3	16	31	22.6
W. R. Perfection	15	9	6	5	8	12	9.1

S.E. = 4.5

Table 14

Analysis of Variance of Starch Grains
With Class 4 Hylum

Due to	D.F.	Variance	F. Value Calc.	F. Value Table 5%	F. Value Table 1%
Total	29	174.17			
Rep.	5	164.11			
Var.	4	442.78	3.60*	2.87	4.43
Error	20	122.96			

Table 15

Number of Starch Grains With **Class 2 Hylum**

Replication / Variety	I	II	III	IV	V	VI	Mean
Early Perfection	23	10	12	12	16	24	16.1
Dark Seeded Perfection	9	17	23	29	13	13	17.3
Perfection Freezer	14	12	17	31	29	22	20.8
New Line Perfection	34	32	15	15	15	13	20.6
W. R. Perfection	5	13	14	13	13	13	11.8

Table 16

Analysis of Variance of Starch Grains
With Class 2 Hylum

Due to	D.F.	Variance	F. Value Calc.	F. Value Table 5%	F. Value Table 1%
Total	29	55.68			
Rep.	5	8.91			
Var.	4	82.45	N.S. 1.28	2.87	4.43
Error	20	64.25			

Table 17

Number of Starch Grains With Class 3 Hylum

Replication / Variety	I	II	III	IV	V	VI	Mean
Early Perfection	10	20	3	17	14	16	13.3
Dark Seeded Perfection	23	13	30	17	12	24	19.8
Perfection Freezer	17	20	11	14	19	28	18.1
New Line Perfection	15	12	19	6	10	17	13.1
W. R. Perfection	8	25	8	10	15	9	12.5

Table 18

Analysis of Variance of Starch Grains
With Class 3 Hylum

Due to	D.F.	Variance	F. Value		
			Calc.	Table 5%	Table 1%
Total	29	41.62			
Rep.	5	29.12			
Var.	4	67.46	N.S. 1.70	2.87	4.43
Error	20	39.58			

Table 19

Analysis of Variance of Regression of Class 3 Hylum on Pea Size

Due to	D.F.	S.S.	Variance	F. Value			r^2
				Cal.F.	Table F.		
					5%	1%	
Total	5	184.92	36.982				
Regression	1	175.38	175.38	73.53**	7.71	21.20	0.9484
Error	4	9.54	2.385				

Table 20

Analysis of Variance of Regression of Class 4 Hylum on Pea Size

Due to	D.F.	S.S.	Variance	F. Value			r^2
				Cal.F.	Table F.		
					5%	1%	
Total	5	3073.60	614.72				
Regression	1	2201.92	2201.92	10.10*	7.71	21.20	0.8367
Error	4	871.68	217.92				

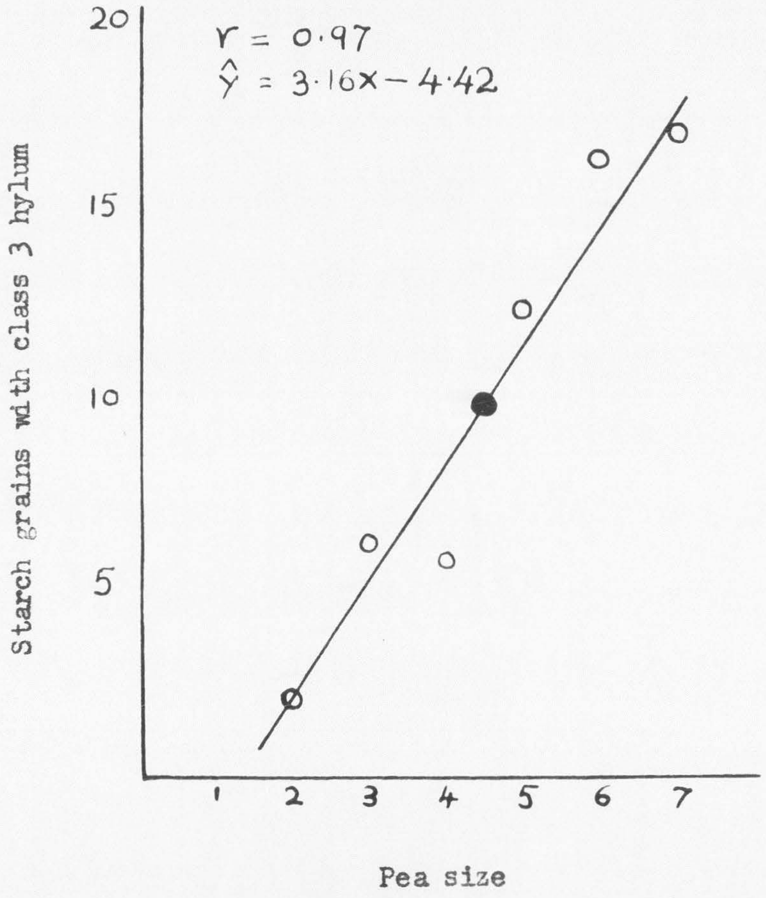

Fig. 10 Regression of class 3 hylum on pea size

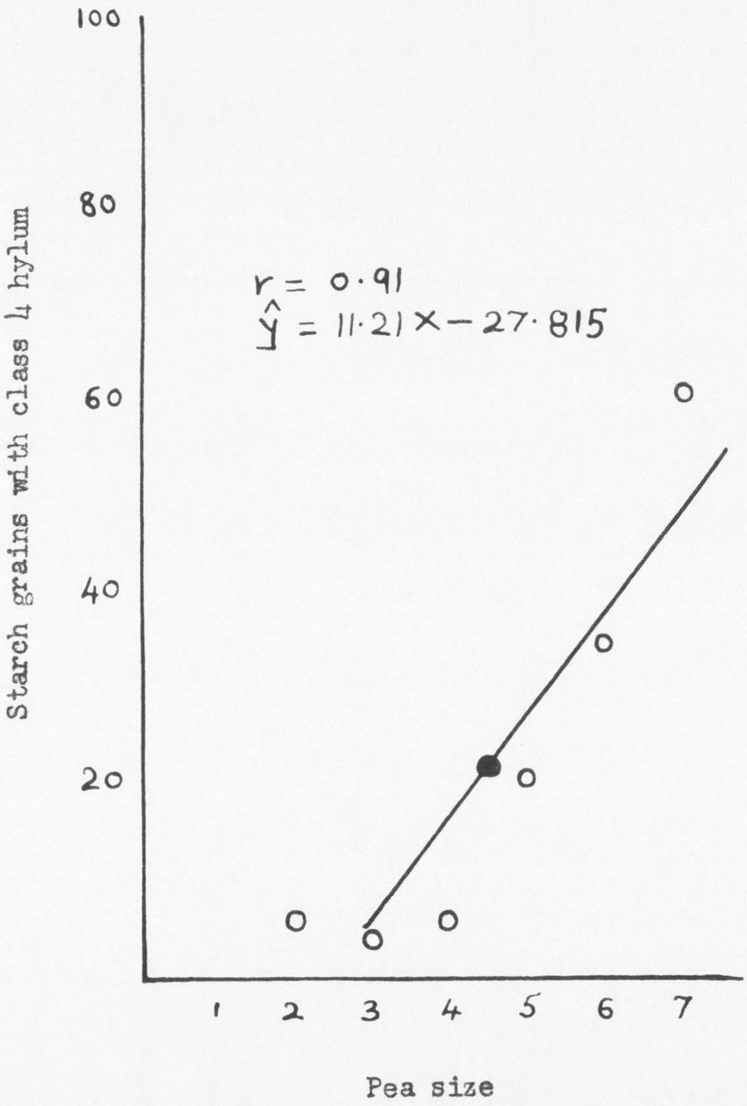

Fig. 11 Regression of class 4 hylum on pea size

number of starch grains with class 3 and 4 hylum development. With an increase in pea size there is a corresponding increase in the number of starch grains having a hylum development of 3rd and 4th class. Hylum of class 2 does not show a correlation with pea size (Tables 21 and figure 12). The regression of number of starch grains having class 1 hylum on pea size shows that (table 22 and figure 13) there is a significant and very definite negative correlation. With an increase in the size of pea the number of starch grains with class 4 hylum development increases.

Table 21

Analysis of Variance of Regression of Class 2 Hylum on Pea Size

Due to	D.F.	S.S.	Variance	F. Value			r^2
				Cal.F.	Table F. 5%	Table F. 1%	
Total	5	176.44	35.48				
Regression	1	34.02	34.02	N.S. 0.95	7.71	21.20	0.1928
Error	4	142.42	35.60				

Table 22

Analysis of Variance of Regression of Class 1 Hylum on Pea Size

Due to	D.F.	S.S.	Variance	F. Value			r^2
				Cal.F.	Table F. 5%	Table F. 1%	
Total	5	47,774.74	9,554.94				
Regression	1	44,194.062	44,194.062	** 49.36	7.71	21.20	.9250
Error	4	3,580.678	8,95.169				

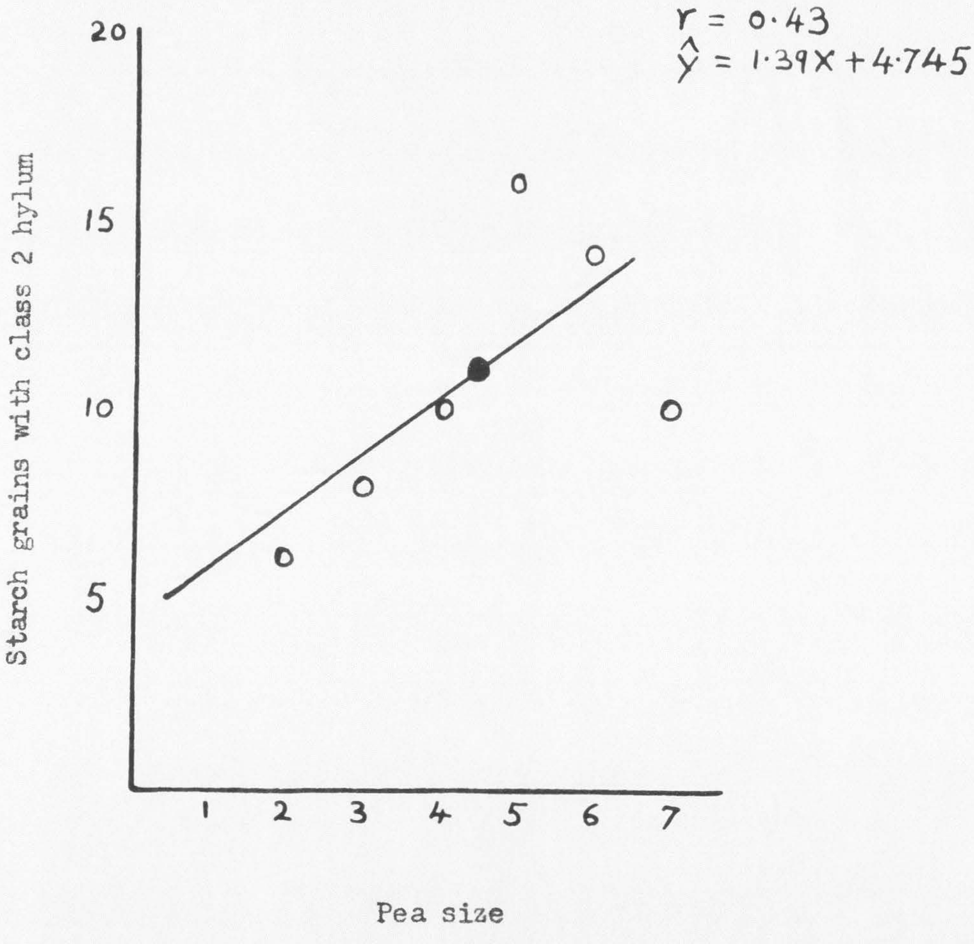

Fig. 12 Regression of class 2 hylum on pea size

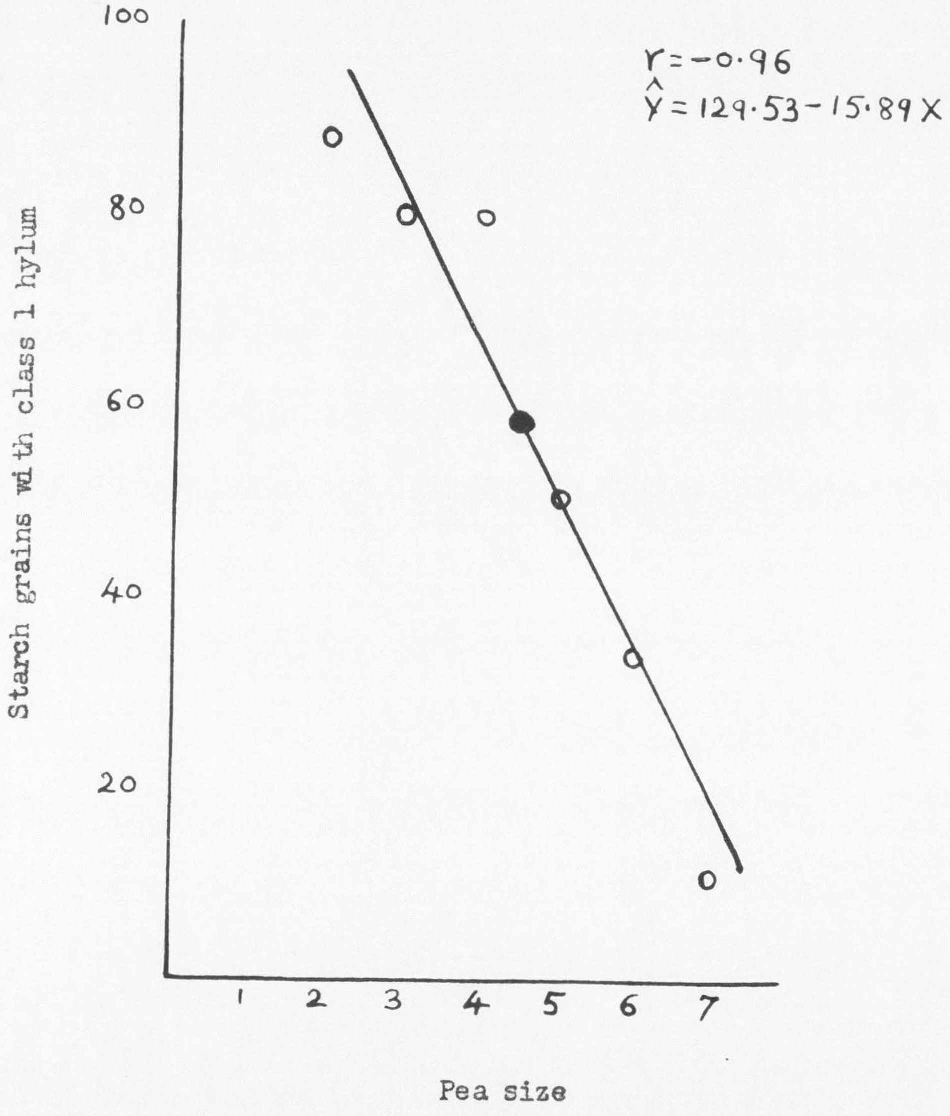

Fig. 13 Regression of class 1 hylum on pea size

SUMMARY AND CONCLUSIONS

Five varieties of peas, Early Perfection, Dark Seeded Perfection, Perfection Freezer, New Line Perfection and W. R. Perfection were planted at the Farmington Research Station, Farmington, Utah, on April 19, 1958. Each plot consisted of 32 rows in 16 feet width, each row being 30 feet in length. Peas were harvested from July 1, 1958 to July 5, 1958. The experiment was designed in a randomized block, with six replications.

Sampling Study

Four samples were collected from each plot. Each sample consisted of eight random grab samples consisting of about thirty plants. The plant density count was taken at every grab, to calculate the yield per acre from the sample yield. The whole plots were harvested. The yield of shelled peas and tenderometer readings were recorded for the samples and complete harvests. The variance of mean of samples for different sample sizes and different number of replications was calculated. The precision of the experiment was set to define the true treatment difference by means of the observed experimental difference ± 5, 10, 20 percent of the overall mean, with 95 percent confidence. For the ± 10 percent precision, the study showed that:

1. With a fixed variance of the mean, four samples with two replications were equivalent to four replications with a complete harvest.

2. Nine replications with complete harvest are equivalent to ten and a half replications with sampling.

3. Sampling is more economic than and as precise as complete harvest.

4. For tenderometer readings, with 10 percent precision 4 samples with five replications gave adequate results.

<u>Varietal Trial and Quality Studies</u>

The peas were studied for tenderometer values, size distribution and microscopic studies viz., size and shape of starch grains and development of hyla. The investigation pointed out that:

1. From the yield point of view there was no difference in the five pea varieties.

2. Tenderometer values showed that Perfection Freezer had significantly lower tenderometer value than Early Perfection and Dark Seeded Perfection. W. R. Perfection had a significantly lower tenderometer reading than Dark Seeded Perfection. The varieties W. R. Perfection, New Line Perfection and Early Perfection were linked. Similarly the varieties New Line Perfection, Early Perfection and Dark Seeded Perfection were linked.

3. With an increase in the size of peas there was an increase in the size of starch grains.

4. There was no difference in the shape of starch grains in all the varieties. Ninety percent of the starch grains were round.

5. As the maturity of the crop advanced the structural development and ramifications of hyla increased.

6. With an increase in the size of pea the number of starch grains with class 4 hylum development increased.

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Appendix table 23 Yield of Shelled Peas in Lb/Acre

Variance of Mean of Samples for Different Sample Sizes
And Different Number of Replications

sampling

No. of Samples / Replications	1	2	3	4	5
4	282,947.5000	156,006.7500	113,693.1666	92,536.3750	79,842.3000
5	226,358.0000	124,805.4000	90,954.5333	74,029.1000	63,873.8400
6	188,631.6666	104,004.5000	75,795.4444	61,690.9166	53,228.2000
7	161,684.2857	89,146.7142	64,967.5238	52,877.9285	45,624.1714
8	141,473.7500	78,003.3750	56,846.5833	46,268.1875	39,921.1500
9	125,754.4444	69,336.3333	50,530.2962	41,127.2777	35,485.4666
10	113,179.0000	62,402.7000	45,477.2666	37,014.5500	31,936.9200
11	102,890.0000	56,729.7272	41,342.9696	33,649.5909	29,033.5636
12	94,315.8333	52,002.2500	37,897.7222	30,845.4583	26,614.1000
13	87,060.7692	48,002.0769	34,982.5128	28,472.7307	24,566.8615
14	80,842.1428	44,573.3571	32,483.7619	26,438.9642	22,812.0857
15	75,452.6666	41,601.8000	30,318.1777	24,676.3666	21,291.2800
16	70,736.8750	39,001.6875	28,423.2916	23,134.0937	19,960.5750
17	66,575.8823	36,707.4705	26,751.3333	21,773.2647	18,786.4235
18	62,877.2222	34,668.1666	25,265.1481	20,563.6388	17,742.7333
19	59,567.8947	32,843.5263	23,935.4035	19,481.3421	16,808.9052
20	56,589.5000	31,201.3500	22,738.6333	18,507.2750	15,968.8460
21	53,894.7619	29,715.5714	21,655.8412	17,625.9761	15,208.0571
22	51,445.0000	28,364.8636	20,671.4848	16,824.7954	14,516.7818
23	49,208.2608	27,131.6086	19,772.7246	16,093.2826	13,885.6173
24	47,157.9166	26,001.1250	18,948.8611	15,422.7291	13,307.0500
25	45,271.6000	24,961.0800	18,190.9066	14,805.8200	12,774.7680
30	37,726.3333	20,800.9000	15,159.0888	12,338.1833	10,645.6400
31	36,509.3548	20,129.9032	14,670.0860	11,940.1774	10,302.2322
32	35,368.4375	19,500.8437	14,211.6458	11,567.0468	9,980.2875

Appendix table 23

Yield of Shelled Peas in Lb/Acre

Variance of Mean of Samples for Different
Sample Sizes and Different Number of Replications

No. of Samples / Replications	6	7	8	9	10
4	71,379.5833	65,334.7857	60,801.1875	57,275.0555	54,454.1500
5	57,103.6666	52,267.8285	48,640.9500	45,820.0444	43,563.3200
6	47,586.3888	43,556.5238	40,534.1250	38,183.3703	36,302.7666
7	40,788.3333	37,334.1632	34,743.5357	32,728.6031	31,116.6571
8	35,689.7916	32,667.3928	30,400.5937	28,637.5277	27,227.0750
9	31,724.2592	29,037.6825	27,022.7500	25,455.5802	24,201.8444
10	28,551.8333	26,133.9142	24,320.4750	22,910.0222	21,781.1660
11	25,956.2121	23,758.1038	22,109.5227	20,827.2929	19,801.5090
12	23,793.1944	21,778.2619	20,267.0625	19,091.6851	18,151.3833
13	21,962.9487	20,103.0109	18,708.0576	17,623.0940	16,755.1230
14	20,394.1666	18,667.0816	17,371.7678	16,364.3015	15,558.3285
15	19,034.5555	17,422.6095	16,213.6500	15,273.3481	14,521.1066
16	17,844.8958	16,333.6964	15,200.2968	14,318.7638	13,613.5375
17	16,795.1960	15,372.8907	14,306.1617	13,476.4836	12,812.7411
18	15,862.1296	14,518.8412	13,511.3750	12,727.7901	12,100.9222
19	15,027.2807	13,754.6917	12,800.2500	12,057.9064	11,464.0315
20	14,275.9166	13,066.9571	12,160.2375	11,455.0111	10,890.8300
21	13,596.1111	12,444.7210	11,581.1785	10,909.5343	10,372.2190
22	12,978.1060	11,879.0519	11,054.7613	10,413.6464	9,900.7545
23	12,413.8405	11,362.5714	10,574.1195	9,960.8792	9,470.2869
24	11,896.5972	10,889.1309	10,133.5312	9,545.8425	9,075.6916
25	11,420.7333	10,453.5657	9,728.1900	9,164.0088	8,712.6640
30	9,517.2777	8,711.3047	8,106.8250	7,636.6740	7,260.5533
31	9,210.2688	8,430.2949	7,845.3145	7,390.3297	7,026.3419
32	8,922.4479	8,166.8482	7,600.1484	7,159.3819	6,806.7687

Appendix table 23

Yield of Shelled Peas in Lbs/Acre

Variance of Mean of Samples for Different Sample Sizes and Different Number of Replications

No. of Samples / Replications	12	14	16	18	30
4	50,222.7916	47,200.3928	44,933.5937	43,170.5277	37,528.7166
5	40,178.2333	37,760.3142	35,946.8750	34,536.4222	
6	33,481.8611	31,466.9285			
7	28,698.7380	26,971.6530			
8	25,111.3958	23,600.1964			
9	22,321.2407	20,977.9523			
10	20,089.1166	18,880.1571			
11	18,262.8333	17,163.7792			
12	16,740.9305	15,733.4642			
13	15,453.1666	14,523.1978			
14	14,349.3690	13,485.8265			
15	13,392.7444	12,586.7714			
16	12,555.6979	11,800.0982			
17	11,817.1274	11,105.9747			
18	11,160.6203	10,488.9761			
19	10,573.2192	9,936.9248			
20	10,044.5583	9,440.0785			
21	9,566.2460	8,990.5510			
22	9,131.4166	8,581.8896			
23	8,734.3985	8,208.7639			
24	8,370.4652	7,866.7321			
25	8,035.6466	7,552.0628			
30	6,696.3722	6,293.3857			
31	6,480.3602	6,090.3732			
32	6,277.8489	5,900.0491			

Appendix table 24

Tenderometer Readings of the Samples of Peas

Variance of Mean of Samples for Different Sample Sizes and Different Number of Replications

Replications \ No. of Samples	1	2	3	4	5	6
4	44.4226	31.5304	27.3163	25.0843	23.7951	22.9356
5	35.5381	25.2243	21.8531	20.0674	19.0361	18.3485
6	29.6150	21.0203	18.2109	16.7229	15.8634	15.2904
7	25.3843	18.0174	15.6093	14.3339	13.5972	13.1060
8	22.2113	15.7652	13.6581	12.5421	11.8975	11.4678
9	19.7433	14.0135	12.1406	11.1486	10.5756	10.1936
10	17.7690	12.6121	10.9265	10.0337	9.5180	9.1742
11	16.1536	11.4656	9.9332	9.1215	8.6527	8.3402
12	14.8075	10.5101	9.1054	8.3614	7.9317	7.6452
13	13.6685	9.7016	8.4050	7.7182	7.3215	7.0571
14	12.6921	9.0087	7.8046	7.1669	6.7986	6.5530
15	11.8460	8.4081	7.2843	6.6891	6.3453	6.1161
16	11.1056	7.8826	6.8290	6.2710	5.9487	5.7339

Appendix table 24

Tenderometer Readings of the Samples of Peas

Variance of Mean of Samples for Different Sample Sizes and Different Number of Replications

No. of Samples / Replications	7	8	9	10	11*	38
4	22.3217	21.8613	21.5032	21.2167	20.9823	19.3168
5	17.8574	17.4890	17.2025	16.9733	16.7858	15.4534
6	14.8811	14.5742	14.3354	14.1444	13.9882	12.8778
7	12.7552	12.4921	12.2875	12.1238		11.0381
8	11.1607	10.9306	10.7516	10.6083		9.6584
9	9.9207	9.7161	9.5569	9.4296		8.5852
10	8.9287	8.7445	8.6012	8.4866		7.7267
11	8.1170	7.9495	7.8193	7.7151		7.0242
12	7.4405	7.2871	7.1677	7.0722		6.4389
13	6.8682	6.7265	6.6163	6.5282		5.9436
14	6.3776	6.2460	6.1437	6.0619		5.5190
15	5.9524	5.8296	5.7341	5.6577		5.1511
16	5.5804	5.4653	5.3758	5.3041		4.8292

*From 11 replications onwards until 38 replications, the value of the variance of mean changes very gradually hence the intermediate figures are ommitted.

Appendix table 25 Variance of Mean of Subplots for Different Plot Sizes and Different Number of Replications

No. of Plots / Replications	1	2	3	4	5
4	157,784.2500	79,429.6250	53,311.4166	40,252.3125	32,416.8500
5	126,227.4000	63,543.7000	42,649.1333	32,201.8500	25,933.4800
6	105,189.5000	52,953.0833	35,540.9444	26,834.8750	21,611.2333
7	90,162.4285	45,388.3571	30,463.6666	23,001.3214	18,523.9142
8	78,892.1250	39,714.8125	26,655.7083	20,126.1562	16,208.4250
9	70,126.3333	35,302.0555	23,693.9629	17,889.9166	14,407.4888
10	63,113.7000	31,771.8500	21,324.5666	16,100.9250	12,966.7400
11	57,376.0909	28,883.5000	19,385.9696	14,637.2045	11,787.9454
12	52,594.7500	26,476.5416	17,770.4722	13,417.4375	10,805.6166
13	48,549.0000	24,439.8846	16,403.5128	12,385.3269	9,974.4153
14	45,081.2142	22,694.1785	15,231.8333	11,500.6607	9,261.9571
15	42,075.8000	21,181.2333	14,216.3777	10,733.9500	8,644.4933
16	39,446.0625	19,857.4062	13,327.8541	10,063.0781	8,104.2125
17	37,125.7059	18,689.3235	12,543.8627	9,471.1323	7,627.4941
18	35,063.1667	17,651.0277	11,846.9814	8,944.9583	7,203.7444
19	33,217.7368	16,722.0263	11,223.4561	8,474.1710	6,824.6000
20	31,556.8500	15,885.9250	10,662.2833	8,050.4625	6,483.3700

Appendix table 26

Analysis of Variance of Yield of Shelled Peas
in Lbs/Acre of Whole Plots and Samples

Whole Plots[1]			Samples			
Due to	D.F.	Mean Sq.	Due to	D.F.	Mean Sq.	
Rep	5	809,104	Rep	5	8,765,470	
var.	2	433,276	Var.	2	~~1,271,091~~	12,710,914
Error	10	317,703	Error	10	~~6,745,707~~	1,480,582
			Sampling	54	40,503	1,015,527

[1] Values for whole plots are twice that of the values for half plots.

$\hat{\sigma}_s^2 = 1,015,527$

$\hat{\sigma}_p^2 = 116,264$

Appendix table 27

Yield of Shelled Peas in Lbs/Acre of Half Plots

Replication / Variety		I	II	III	IV	V	VI	
Early Perfection	a	5392	5618	4426	7277	3878	6452	
	b	4847	6117	4608	4102	5057	3866	
		10239	11735	9034	11379	8935	10318	61640
Dark Seeded Perfection	a	4805	5454	5664	6047	5947	6328	
	b	4533	5726	6117	5865	5494	6010	
		9338	11180	11781	11912	11441	12338	67990
Perfection Freezer	a	4167	6769	5505	5899	5433	5886	
	b	3713	6860	4961	4901	5070	4662	
		7880	13629	10466	10800	10503	10548	63826
		27457	36544	31281	34091	30879	33204	193456

Overall Mean = 5373

Appendix table 28

Analysis of Variance of the Yield of Shelled Peas in Lbs/Acre of Half Plots

Due to	D.F.	S.S.	Mean Square
Total	35	27,460,049	784,572.82
Rep.	5	8,088,161	161,763.22
Var.	2	1,734,445	867,222.50
Error	10	6,354,379	635,437.90
Sampling	18	11,283,064	626,836.88

$$= \frac{635,437.9}{2x6} = 52,950.5$$

Appendix table 29

Yield of Shelled Peas in Lbs/Acre Calculated From Samples

Variety	Replication / Sample	I	II	III	IV	V	VI	
Early Perfection	1	7860	7113	4727	7957	5640	4993	
	2	5883	9938	5626	7614	6265	3953	
	3	6210	7567	6652	7805	4963	4572	
	4	5445	7912	5104	7033	6798	6650	
		25398	32530	22109	30409	23666	20168	154280
Dark Seeded Perfection	1	8439	7555	7600	9264	6776	7882	
	2	7033	7713	8849	7998	6705	7364	
	3	5973	9689	5522	7260	7505	7591	
	4	7156	8338	5641	10297	7958	7061	
		28601	33295	27612	34819	28944	29898	183169
Perfection Freezer	1	7040	7252	5889	5897	6699	5803	
	2	5155	10109	6097	6444	4020	6232	
	3	5579	7235	6202	6189	5967	4501	
	4	6790	8407	6434	4948	7519	5309	
		24564	33003	24622	23478	24205	21845	151717
		78563	98828	74343	88706	76815	71911	489166

Overall mean 6791 lbs/acre.

Appendix table 30

Tenderometer Readings of Shelled Peas for the
3 Varieties Under Sampling Study

Variety	Sample	I	II	III	IV	V	VI
Early Perfection	1	117	131	101	142	108	111
	2	108	118	110	151	117	115
	3	121	145	105	140	106	114
	4	107	127	106	131	125	120
Dark Seeded Perfection	1	156	121	115	126	108	166
	2	151	124	114	128	113	163
	3	152	140	113	127	111	122
	4	168	129	120	129	108	117
Perfection Freezer	1	121	110	99	99	97	105
	2	102	107	102	100	98	110
	3	103	110	99	101	96	101
	4	123	106	105	100	101	110

Appendix table 31

Analysis of Variance of Yield of Pea Tenderometer
Readings

Due to	D.F.	M.S.	Cal.F.	Table F. 5%	Table F. 1%
Total	71	309.8239			
Rep.	5	879.80			
Var.	2	4,007.79	9.9857**	4.10	7.56
Sampling	54	103.1374	0.2569		
Error	10	401.35			

Appendix table 32

Yield of Shelled Peas in Lbs/Acre of Whole Plots

Variety \ Replication	I	II	III	IV	V	VI	Mean
Early Perfection	5120	5868	4517	5689	4467	5159	5136.66
Dark Seeded Perfection	4669	5590	5891	5956	5721	6168	5665.83
Perfection Freezer	3940	6815	5233	5400	5251	5274	5318.83

Appendix table 33

Analysis of Variance of Peas from Whole Plots

Due to	D.F.	M.S.	Cal.F.	Table F. 5%	Table F. 1%
Total	17	475,891.83			
Rep.	5	808,831.16			
Var.	2	433,611.10	1.36 n.s.	4.10	7.56
Error	10	317,878.32			

Appendix table 34

Tenderometer Readings of Shelled Peas for the
3 Varieties Under Sampling Study

Replication / Variety	I	II	III	IV	V	VI	Mean
Early Perfection	118	129	98	126	107	106	114.00
Dark Seeded Perfection	143	122	111	111	105	119	118.50
Perfection Freezer	113	110	94	95	92	103	101.16

Appendix table 35

Analysis of Variance of Pea Tenderometer Readings

Due to	D.F.	M.S.	Cal.F.	Table F. 5%	Table F. 1%
Total	17	178.0653			
Rep.	5	281.9555			
Treat.	2	485.3889	75.842**	4.10	7.56
Error	10	64.6555			